Lake Trout Exploitation Stress Assessment on Drag, Dickey, and Twelve Mile Lakes

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Abstract

Exploitation stress was assessed for the native lake trout populations of Drag, Dickey, and Twelve Mile Lakes. Winter, spring, and summer creel surveys and fall trap and gillnet studies were carried out from 1981 to 1985. Drag Lake, where angling effort was moderate (5.8 ang-hrs/ha/yr), CUE was high (0.266), and annual yield was not excessive (0.33 kg/ha, RORY=66%), was not overexploited during the study period. Though mortality rates were moderate to high, spawning escapement was sufficient to allow increased recruitment to this lake's fishery over the study period. Dickey Lake was clearly overexploited during the study period. Annual effort (21.6 ang-hrs/ha), yield (0.82 kg/ha, RORY=113%), mortality (0.79), and variation in abundance and year class strength were high, and CUE (0.099) and mean age at maturity (4.6 years) were low, all indicating a stressed population. Twelve Mile Lake may not have been overexploited during the study period. Annual effort (9.1 ang-hrs/ha), yield (0.46 kg/ha, RORY=78%), and mortality (0.49) were all considered moderate to high. However, very low angler CUE (0.060), high variation in abundance and year class strength, and poor spawning escapement suggest that Twelve Mile Lake was overexploited in the past. We recommend that steps should be taken to reduce lake trout exploitation on Dickey and Twelve Mile Lakes.

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Introduction

Exploitation is a major stress on Ontario lake trout stocks. In order to identify overexploitation of a stock before it begins to fail (i.e. decreased yields or complete collapse of the fishery), SPOF Working Group 15 (Ontario 1983) suggested the use of biological attributes. The working group proposed a number of indicators of overexploitation relating to yield, abundance, age structure, growth, and maturity. The primary objective of this report is to determine the level of exploitation in three Haliburton-Hastings Fisheries Assessment Unit lake trout lakes through application of these indicators.

We consider the data series on these lakes adequate to monitor fish community responses to stress (SPOF Working Group 1). Therefore, a second objective is to provide baseline estimates of these indicators for comparisons with other lakes and to our study lakes over time. This information will be especially useful for the preparation of FAU lake synopses and community type syntheses (Ontario 1984).

In this report we focus on native lake trout only. Though the lake trout stocks in the study lakes are supplemented with hatchery reared fish, native fish formed the bulk of the harvest (92% by number of native fish in Drag Lake, 70% in Dickey and Twelve Mile Lakes over the period 1981 to 1985). Lake trout stocking assessments for these

lakes will be reported elsewhere (e.g. Stewart 1987).

This report represents one of the first detailed exploitation stress assessments for native lake trout in small Ontario lakes (see also Barnes et al. 1984).

Study Lakes

Drag Lake (45°04'N, 78°23'W) is a 1031 ha lake trout/smallmouth bass lake (Community 18, Ontario 1978) with a MEI of 2.17 (mean depth=17.8 m) and a potential fish yield of 1.99 kg/ha/yr. Other fish species include lake herring, largemouth bass, rock bass, pumpkinseed, yellow perch, white sucker, longnose sucker, brown bullhead, brook stickleback, brook trout, Iowa darter, and cyprinids. Alkalinity and pH are high suggesting that Drag Lake is not presently vulnerable to acidification (TIP alkalinity=20 mg/l, pH=7.0). Low nutrient levels suggest that cultural eutrophication is not a problem (total nitrogen=0.40 mg/l, total phosphorus=0.005 mg/l).

Dickey Lake (44°47'N, 77°23'W) is a 214 ha lake trout/smallmouth bass lake (community 18) with a MEI of 4.94 (mean depth=18.3 m) and a potential fish production of 2.87 kg/ha/yr. The lake trout are primarily planktivorous, thus growth is slow. Largemouth bass, yellow perch, rock bass, pumpkinseed, fallfish, brown bullhead, white sucker, creek chub, and other cyprinids are also present. Alkalinity and pH are high (TIP alkalinity=54 mg/l, pH=7.4) and nutrient levels are low (total nitrogen=0.44 mg/l, total phosphorus=0.005 mg/l). However,

increased cottage development since the construction of an access road in 1969 may have resulted in increased nutrient input.

Twelve Mile Lake (45°01'N, 78°43'W) is a 463 ha lake trout/smallmouth bass/lake whitefish lake (community 26) with a MEI of 3.21 (mean depth=18.3 m) and a potential fish production of 2.37 kg/ha/yr. Lake trout are primarily piscivorous. Rainbow smelt, introduced in the 1950's are abundant. Other species include lake herring, largemouth bass, rock bass, pumpkinseed, yellow perch, burbot, and cyprinids. Twelve Mile Lake is moderately sensitive to acidification (TIP alkalinity=9.5 mg/l, pH=7.0). Present nutrient levels are low (total nitrogen=0.37 mg/l, total phosphorus=0.005 mg/l).

Shoreline development is extensive in all three lakes (8, 15, and 17 cottages per km of shoreline for Drag, Dickey, and Twelve Mile Lakes respectively). Therefore, the potential for increased nutrient levels, (with concomitant reduction in dissolved oxygen concentrations), and the destruction of fish habitat is high. However, effort and yield data suggest that exploitation presently exerts the greatest potential stress on these lake trout populations.

Methods

The native lake trout populations of Drag, Dickey, and Twelve Mile Lakes formed the basis of this study. Roving stratified creel surveys (Lester and Trippel 1985) were conducted during winter, spring, and summer seasons from 1981 to 1985 (Table 1). Supplementary fall trap and gillnet sampling provided samples of lake trout of a size larger and smaller than those normally taken by anglers. Fall sampling included concentrated effort on spawning shoals in Drag (1983 and 1985) and Twelve Mile (1984) Lakes. No fall sampling was conducted on Dickey Lake.

Creel survey catch statistics were calculated and summarized using the CREESYS program (Lester and Trippel 1985). Scales gave more consistent ages than other bony structures and thus scale ages are reported here. Fork length was measured to the nearest 1 mm and weight to 10 grams. State of maturity is reported for female trout only. Those possessing large ovaries with maturing or atretic eggs were considered mature.

The 'indicators' of exploitation described by SPOF 15 (Ontario 1983 - see below) were calculated for each fishery.

Angling Effort

Annual angling effort (angler-hours/ha) was estimated by combining the mean angling efforts of spring, summer, and winter creel surveys calculated over the study period (1981-1985).

Table 1. Summary of winter, spring, and summer creel surveys (CR) and fall trap-(TN) and gill-(GN) netting including gillnetting on spawning shoals (GNS) for Drag, Dickey, and Twelve Mile Lakes.

	Drag	Dickey	Twelve Mile
1981 Winter	CR	CR	CR
Spring	CR	CR	CR
Summer	CR	CR	CR
1982 Winter	CR	CR	
Spring	CR	CR	CR
Summer		CR	
Fall	GN		
1983 Winter	CR	CR	CR
Spring	CR		CR
Summer	CR		CR
Fall	TN & GNS		
1984 Winter	CR	CR	CR
Spring	CR	CR	CR
Summer	CR	CR	CR
Fall			TN & GNS
1985 Winter	CR	CR	CR
Spring	CR		CR
Summer	CR		CR
Fall	TN & GNS		TN

Yield

The ratio of observed to recommended species yield (RORY - Schlesinger and MacLean 1983) is defined here as,

RORY=current lake trout yield/potential lake trout yield,

where current lake trout yield is the total annual angling yield of native lake (kg/ha/yr); and

$$\text{lake trout potential yield} = 1.4\ (\text{MEI})^{0.45} \times 25\%$$

(see SPOF 12 - Ontario 1982). A RORY greater than 100% indicates a high degree of exploitation.

Abundance

Catch per unit effort (CUE) data were used to estimate lake trout abundance (assuming constant catchability). Total observed CUE (number caught per angler hour) for all seasons and years combined was used as a measure of angling quality for each lake. Variation in abundance was described by the coefficient of variation in mean annual winter and spring/summer CUE's. The winter ice fishery and spring/summer open water season were separated for the latter analysis because their CUE's are not comparable due to basic differences in angling methods and therefore catchability. The SPOF 15 report (Ontario 1983) recommends that a coefficient of variation of 0.35 is a threshold for concern for lake trout.

Age Structure

Winter harvest per unit effort (HUE) data were chosen to calculate mortality, mean age of the harvest, and the relative abundance of individual cohorts for the following reasons:

i) larger sample of aged fish in winter;

ii) less variation in size at age which affects recruitment;

iii) variation in the timing of annulus formation (in spring) may cause aging errors;

iv) more years were sampled in the winter;

v) the winter creel survey was more complete, i.e. higher proportion of estimated effort, catch, and harvest was observed in winter; and

vi) higher proportion of angler effort, catch, and harvest occurs in winter.

We recognize the need, in other studies, to utilize spring/summer data, either simply to increase sample size or because winter data are unavailable (eg. winter angling closures). Therefore, we include Appendix A to contrast winter and spring/summer estimates of mortality, mean age of the harvest, and variation in year class strength.

Mortality

Total annual mortality (A) was estimated using the average annual age specific HUE's of lake trout harvested during the winter and calculated using Heincke's estimate (Ricker 1975), $A=N_0/\leq N$, where N_0 is the HUE of the first fully recruited age and $\leq N$ is the total HUE of all fully recruited age classes. The first fully recruited age was considered to be the modal age plus one (Ricker 1975). Constant annual recruitment, mortality, and catchability were assumed. Total annual mortalities greater than 0.5 are considered to entail high risk of instability or collapse of the lake trout fishery (SPOF 15 -

Ontario 1983). Heincke mortality estimates are contrasted with regression mortality estimates based on catch curve analysis (Ricker 1975) in Appendix B.

Mean Age of the Harvest

Mean age of the harvest was calculated, by sex, for all winter angled native lake trout. Data were combined where there was no significant differences between the sexes (t-test, p=.05).

Variation in Year Class Strength

We examined variation in year class strength in two ways. The coefficient of variation for mean age of the winter harvest was determined for each lake. It was assumed that a high variation in mean age was at least partially attributable to variation in year class strength. In addition, we used a type of cohort analysis to estimate the relative abundance of each cohort at the age of full recruitment.

Using the catch equation (see Ricker 1975), the harvest (C_R) of a cohort in its first year of full recruitment (R) is equal to the product of a catchability coefficient (q), the population size of the cohort (N_R), and the fishing effort for that year (E_R),

$$C_R = q \cdot N_R \cdot E_R \qquad (1).$$

The harvest of a cohort in any year (t) following full recruitment to the fishery is:

$$C_{R+t} = q \cdot N_R \cdot E_{R+t} \cdot S^t \qquad (2),$$

where t is the number of years after the age of full recruitment and S is the annual survival rate. Thus, $\lesssim C_{R+t}$, the total harvest of a cohort over a number of years, is estimated by,

$$\sum_{t=0}^{k} C_{R+t} = q \cdot N_R \cdot \sum_{t=0}^{k} E_{R+t} \cdot S^t \qquad (3),$$

where k is the number of sampling years. Therefore, our estimate of $q \cdot N_R$ for each cohort is:

$$q \cdot N_R = \lesssim C_{R+t} \; / \; \lesssim E_{R+t} \cdot S^t \qquad (4).$$

The observed total winter harvest of each cohort was used in equation (4) to calculate the relative abundance ($q \cdot N_R$) of each cohort at the age of full recruitment (R).

The $q \cdot N_R$ values estimate the HUE at recruitment age, integrating all available sample data. Furthermore, this method allows for back-calculation of recruitment age HUE for cohorts not sampled in their year of first recruitment. The method assumes constant

mortality and constant catchability beyond recruitment age. Plots of the $q \cdot N_R$ values provided a graphic description of the changes in year class strength over time. The coefficient of variation for the $q \cdot N_R$ values was used as an index of variation in year class strength.

Growth

Growth, measured as increase in fork length, was presented in two ways. Values for mean length at age for native lake trout angled in winter and supplemented by fall trap and gillnet samples were fitted to the Von Bertalanffy growth model,

$$l_t = L_{inf} \cdot (1 - \exp(-K \cdot (t - t_o)))$$

where l_t is the fork length (cm) at age t, L_{inf} is the asymptotic fork length, K is a growth rate coefficient, and t_o is a time when length would theoretically be zero. Growth model parameters were estimated using the RS/1 'fit function' routine (BBN Software Products Corporation 1984). In addition, mean fork length at age was compared to the 'growth standard' (mean fork length at age) for Ontario lake trout (SPOF 15 - Ontario 1983).

Age At Maturity

Mean age at maturity was calculated for female native lake trout by three methods: probit analysis; modified Abrosov method; and

Lysak's method (Ritchie 1984). Mean age at maturity was compared to the mean age of female lake trout angled over the study period using Abrosov's t-value (mean age of harvest - mean age at maturity). These values represent the number of spawning opportunities of the 'average' individual. High t-values suggest stability within the population (SPOF 15 - Ontario 1983).

Age-frequency distributions of native lake trout trapped on the spawning shoals of Drag (1983 and 1985 combined) and Twelve Mile (1984) Lakes were plotted. The age composition of spawning populations was compared to the mean age at maturity to examine survival beyond maturity and opportunities for multiple spawnings.

Results

Angling Effort

Estimated annual angling effort was higher in Dickey Lake at 21.6 angler-hours/ha than Twelve Mile (9.1) or Drag (5.8) Lakes. Angling effort was greater in winter making up 55% of the annual effort in Dickey and Drag Lakes, and 75% in Twelve Mile Lake. Effort has remained fairly consistent over the five-year study period except for a decline in Drag Lake from 7.2 angler-hours/ha in 1983 to 4.3 in 1985.

Yield

Lake area, MEI, potential fish production, recommended lake trout yield (Ontario 1982), estimated mean annual native lake trout yield, and the ratio of observed to recommended yield (RORY) are shown in Table 2.

Ratios of observed to recommended lake trout yields, for years of complete creel data, indicate that Dickey Lake native lake trout were harvested above the recommended maximum level (mean RORY=113%) while those in Drag and Twelve Mile Lakes were harvested somewhat below the maximum level (66 and 78% respectively).

Native lake trout yields varied annually (see range in RORY, Table 2). The recommended maximum RORY (100%) was exceeded in at least one year in all three lakes.

Table 2. Selected physical, chemical, and biological attributes of Drag, Dickey, and Twelve Miles Lakes (area and MEI taken from Hulsman 1983).

Lake	Area (ha)	MEI	Potential Fish Production (kg/ha/yr)	Lake Trout Yield		RORY	
				Recommended (kg/ha/yr)	Estimated (kg/ha/yr)	%	Range
Drag	1031	2.50	2.11	0.53	0.33	62	41 - 103
Dickey	214	4.92	2.87	0.72	0.82	113	87 - 166
Twelve Mile	463	3.21	2.37	0.59	0.46	78	37 - 107

Abundance

Total observed CUE was 0.060/angler-hour in Twelve Mile Lake, 0.099 in Dickey and 0.266 in Drag Lake.

The coefficient of variation in winter and spring/summer CUE's was greater than that recommended by SPOF 15 (0.35, Ontario 1983) in Twelve Mile (0.61 and 0.81 respectively) but less in Drag Lake (0.32 in both seasons). In Dickey Lake, the coefficient of variation in CUE was greater than the recommended value in winter (0.43) but less in the spring/summer season (0.26).

Age Structure - Mortality

The average annual HUE's by age of winter angled native lake

trout are shown in Figure 1 for Drag, Dickey, and Twelve Mile Lakes. Calculations of mortality based on these data assume constant recruitment and equal catchability of all age classes, and are influenced by the age of full recruitment into the fishery. Assuming the modal age plus one to be the first fully recruited year class (Ricker 1975), total annual mortality was 0.72 in Drag, 0.64 in Dickey, and 0.49 in Twelve Mile Lake as calculated by the Heincke method. In Dickey Lake, total annual mortality was 0.79 when the model age was included, therefore, this higher value was considered the better estimate. Mortality exceeded that which may entail high risk of instability (0.50, SPOF 15 - Ontario 1983) in Drag and Dickey Lakes.

Mean Age of the Harvest

There were no significant differences between sexes in the mean age of winter angled fish. In Drag Lake, the mean age of the harvest was 5.8 years (n=592), increasing slightly over the study period from 5.3 (n=112) in the winter of 1981 to 6.0 (n=141) in 1985. The mean age of the harvest in Dickey Lake was 6.3 (n=306), again increasing slightly over the study period from 5.9 (n=19) in 1981 to 6.8 (n=100) in 1985. In Twelve Mile Lake, the mean age of the harvest was 5.8 (n=181), ranging from 5.4 (n=91) in 1984 to 6.3 (n=45) in 1985.

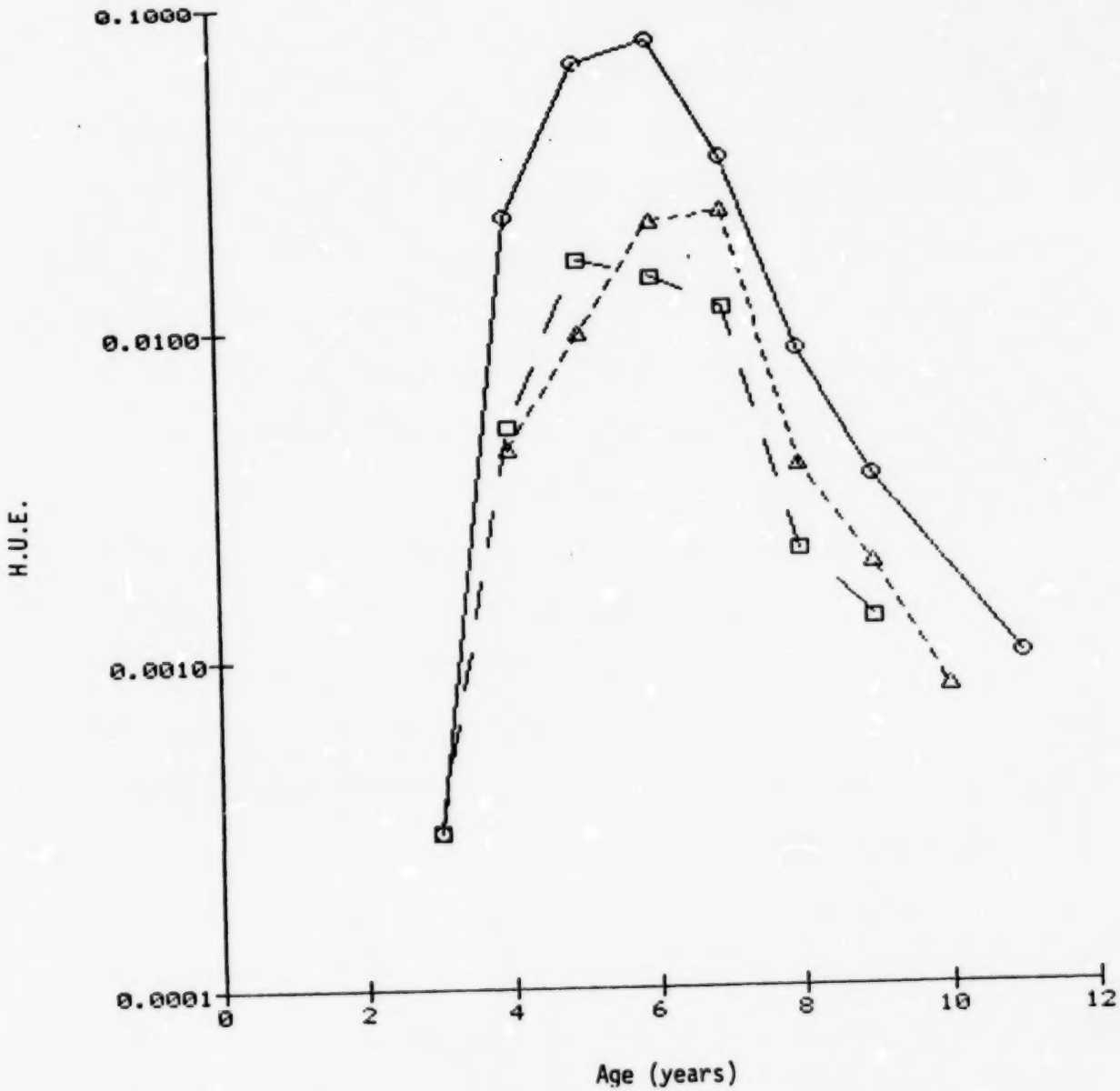

Figure 1. Average annual HUE by age of winter angled native lake trout in Drag (circles), Dickey (triangles), and Twelve Mile (squares) Lakes.

Variation in Year Class Strength

Variation in mean age among years, for winter angled fish, was greater in Twelve Mile (coefficient of variation = 0.07, mean = 5.8 years) than Dickey (C.V. = 0.06, mean = 6.3) or Drag (C.V. = 0.05, mean = 5.8) Lakes (sexes combined).

The estimates of relative abundance at recruitment age ($q \cdot N_R$) for each cohort are plotted in Figure 2a-c for Drag, Dickey, and Twelve Mile Lakes. For comparison, observed cohort winter HUE's at recruitment age are also shown. There was generally good agreement between the observed HUE's and the integrated estimates. Lake trout were considered fully recruited at ages 7 and 6 (modal age + 1) in Drag and Twelve Mile Lakes respectively. In Dickey Lake, lake trout were considered fully recruited at age 7 (modal age) because mortality estimates were higher when this age class was included (see above).

In Drag Lake, the youngest chorts (1976-1978) and the oldest cohort (1972) were more abundant than the 1973 to 1975 cohorts. The highest relative abundance (1972) was about three-fold greater than the lowest relative abundance (1974).

In Dickey Lake, there was an apparent increase in the abundance of individual cohorts after 1974 with about a six-fold increase by 1978. The same trend is apparent in the observed HUE's. The HUE of the 1974 cohort in the winter of 1981 (at age 7) was 0.008 compared to the HUE (0.044) for the 1978 cohort in the winter of 1985 (also at age 7).

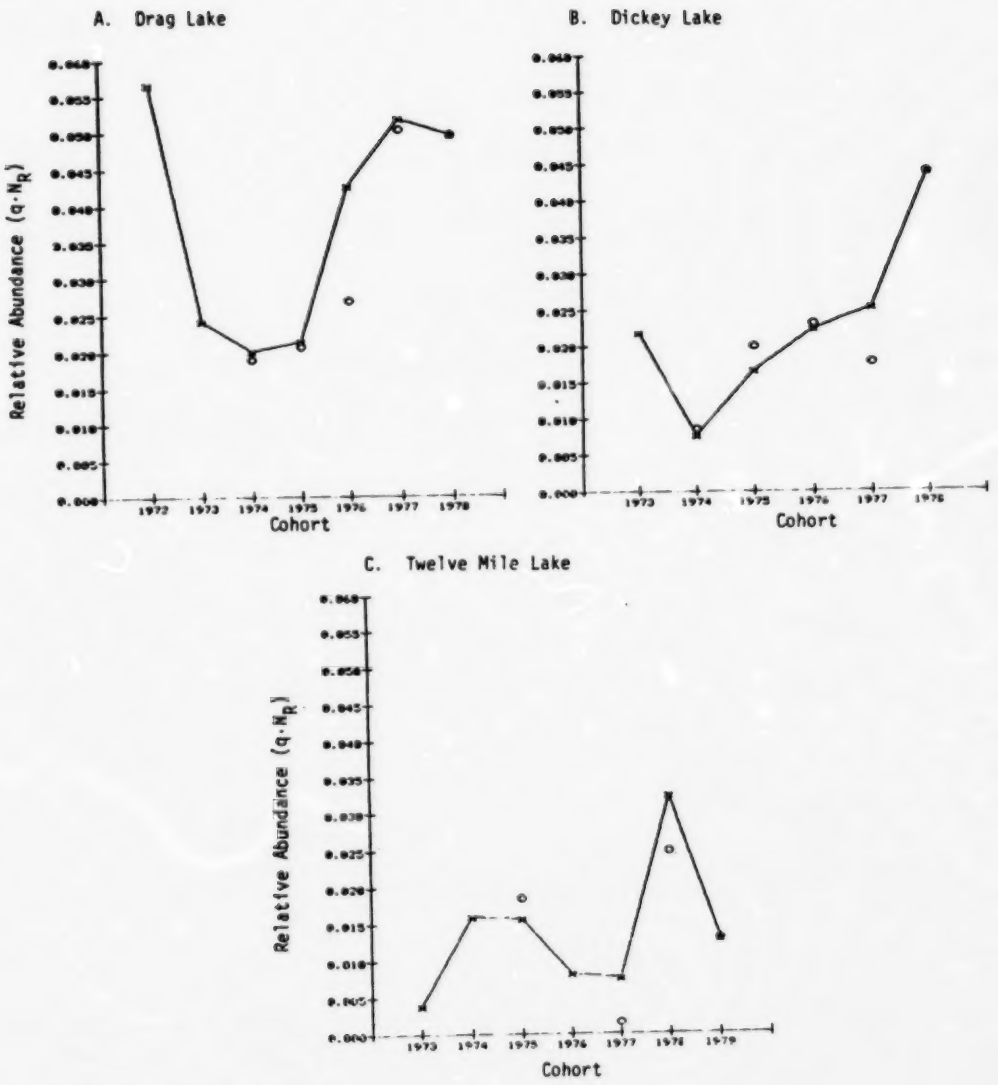

Figure 2. Estimates of the relative abundance at recruitment age ($q \cdot N_R$) for individual cohorts in a) Drag, b) Dickey, and c) Twelve Mile Lakes. Also included are the observed HUE's at recruitment age (circles).

In Twelve Mile Lake, there was no trend in relative abundance at recruitment age. The 1978 cohort had the highest estimated relative abundance and observed HUE (0.025). The lowest estimated relative abundance was for the 1973 cohort while the lowest observed HUE was for the 1977 cohort (0.001).

The coefficients of variation in the relative population abundance estimates at recruitment age were 0.42, 0.52, and 0.73 for Drag, Dickey, and Twelve Mile Lakes respectively.

The results of both methods indicate that variation in year class strength was greatest in Twelve Mile, intermediate in Dickey, and least in Drag Lake.

Growth

Von Bertalanffy growth equation parameters are reported in Table 3. The parameter estimates of the von Bertalanffy growth model did not meet convergence criteria of the RS/1 curve fitting routine for lake trout from Drag Lake. Possible reasons for this are discussed in SPOF 15 - Ontario 1983). Also the L_{inf} values (Table 3) are not realistic for all three populations. We reject the use of this growth model for describing lake trout growth for our data sets.

Fork lengths at age for the native lake trout of Drag, Dickey, and Twelve Mile Lakes are illustrated in Figure 3. Also included for comparison is the growth standard ($\pm$ 95% C.I.) for 'average' Ontario lake trout (SPOF 15 - Ontario 1983). In Drag Lake, growth is very

slow during the first several years of life but rapid after age 7, such that young fish are below the Ontario average length and older fish are similar to the Ontario average (Figure 3a). Growth in Dickey Lake is slower than the Ontario average (Figure 3b). Native lake trout growth in Twelve Mile Lake is similar to the Ontario average (Figure 3c).

Table 3. Von Bertalanffy growth equation parameters for the native lake trout of Drag, Dickey, and Twelve Mile Lakes.

	L_{inf} (cm)	K	t_o
Drag*	270.35	0.024	0.614
Dickey	162.46	0.037	-0.182
Twelve Mile	179.39	0.043	0.279

* data did not fit the growth model

Age at Maturity

Mean age at maturity calculations are listed in Table 4 along with the mean age of female native lake trout harvested by anglers (all seasons and years combined) and the mean age of the female spawning shoal catches. Mean age at maturation was similar for probit

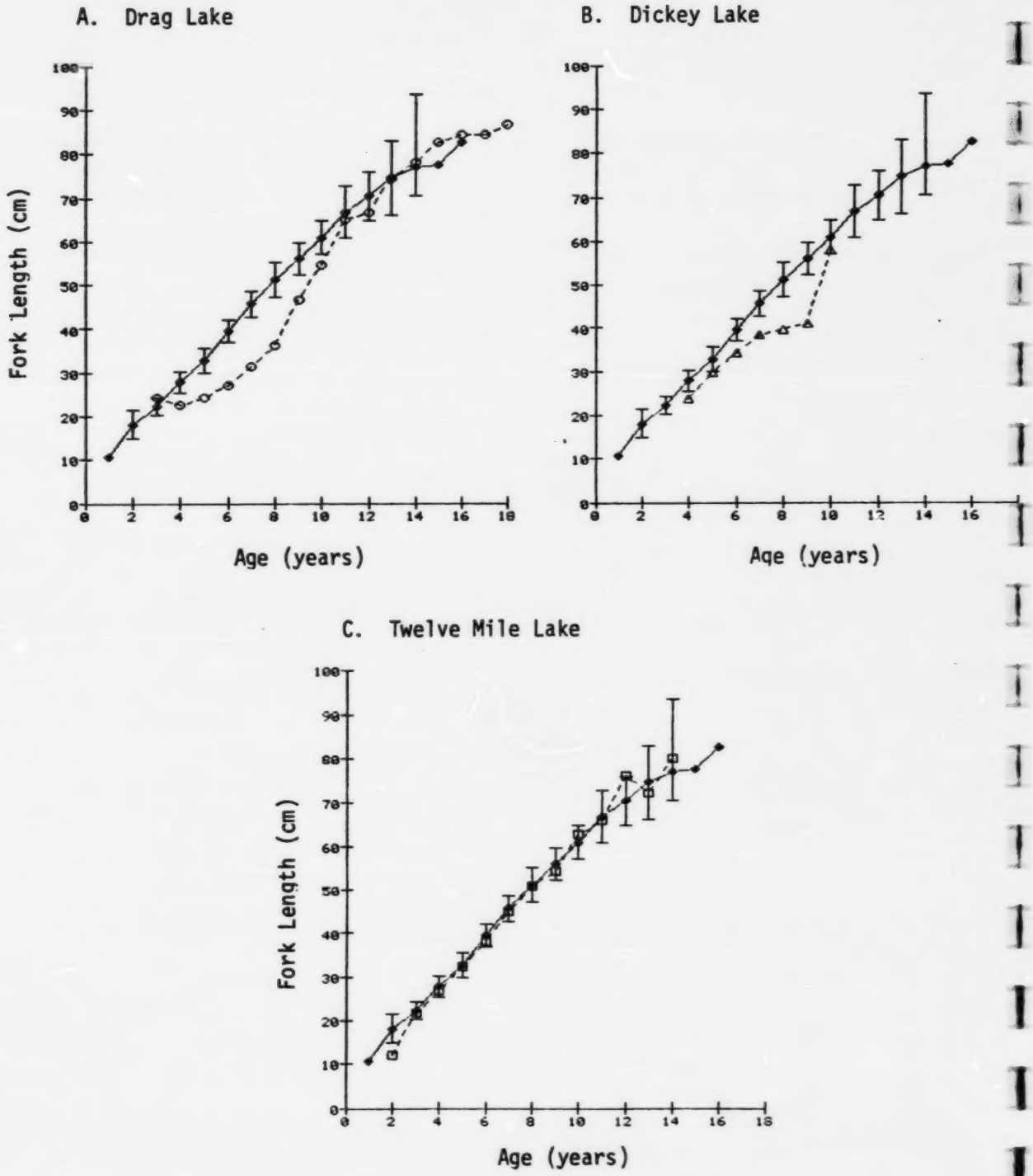

Figure 3. Mean fork length at age for the lake trout of a) Drag (circles), b) Dickey (triangles), and c) Twelve Mile (squares) Lakes, and the Ontario average (±95% C.I., SPOF 15 - Ontario 1983). In Dickey Lake, the age 10 data point represents only one fish.

and Lysak methods and ranged from 4.4 in Dickey to 5.8 in Drag Lake. The modified Abrosov method produced larger values. Ritchie (1984) found that the probit method resulted in mean ages close to the empirically determined age where 50% of the fish would be mature. Therefore, the probit age was used to calculate Abrosov's t-value. Abrosov's t-value was low for Drag (0.4) and Twelve Mile (0.3) Lakes but comparatively high for Dickey Lake (1.8).

Table 4. Mean age at maturation for female lake trout as calculated by three methods. Also given are the mean age of the female harvest, Abrosov's t-value calculated using the probit mean age at maturation, and the mean age of the female spawning population.

	Mean Age at Maturation					
	Probit	Modified Abrosov	Lysak	Mean Age Harvest	t	Mean Spawning Age
Drag	5.8	6.5	5.8	6.2	0.4	10.4
Dickey	4.6	5.3	4.4	6.4	1.8	-
Twelve Mile	5.7	6.2	5.7	6.0	0.3	9.3

The mean age of spawning lake trout was 10.4 (n=78, s.d.=2.3) in Drag Lake (males and females not significantly different, $p \geq .05$), ranging in age from 5 to 17 years for males and 10 to 14 for females. In Twelve Mile Lake, mean age was greater ($p < .05$) for females (9.3, n=14, s.d.=1.8, range 7 to 12) than males (7.4, n=38, s.d.=1.8, range

5 to 13). Though mean age of the spawners was greater in Drag than Twelve Mile Lake, mean fork lengths were similar (58.9 and 57.8 cm for Drag and Twelve Mile Lakes respectively).

Discussion

The indicators of explotation, summarized in Table 5, will serve as a baseline for comparison with other lakes and for detecting changes in our study lakes over time. Also included in Table 5 are brief comments on the interpretation of the indicators based on SPOF 15 (Ontario 1983) recommendations and other studies.

The primary objective of this study was to determine the level of exploitation for each lake. Interpretation of the indicators of overexploitation is not straightforward, for several reasons, including:

1) a population may respond differently than expected to exploitation;
2) there may be a lag time between overexploitation and the response of a population;
3) indicators differ in their scope for change; and
4) an indicator may be measuring a population's response to other stresses (see Colby 1984).

In our interpretation below, we recognize these limitations, point out weaknesses in our data, and make recommendations regarding improved data collection.

Yield, Effort, and Abundance

Maintenance of yield and thus angling opportunities is a basic objective of fisheries managers. Yield data alone are not sufficient

Table 5. Data summary for Drag, Dickey, and Twelve Mile Lakes.

	Drag	Dickey	Twelve Mile	General Comments / SPOF 15 Threshold for Concern
Effort (ang-hr/ha/yr)	5.8	21.6	9.1	We consider 5 ang-hr/ha/yr as moderate pressure.
Annual Yield (kg/ha/yr)	0.33	0.82	0.46	Unlikely for popl'n to withstand annual yields of 0.50 (Martin and Olver 1980).
RORY (%)	66	113	78	100% is maximum sustainable yield.
Abundance (CUE)	0.266	0.099	0.060	
Coefficient of Variation in Abundance:				
Winter	0.32	0.43	0.61	SPOF - 0.35
Spring/Summer	0.32	0.26	0.81	
Mortality (Heincke)	0.72	0.79	0.49	SPOF - 0.50
Mean Age	5.8	6.3	5.8	Declining mean age is an intial popl'n response to exploitation.
Modal Age	6	7	5	

Table 5. Cont'd

	Drag	Dickey	Twelve Mile	General Comments / SPOF 15 Threshold for Concern
Coefficient of Variation in Year Class Strength:				
Mean Age	0.05	0.06	0.07	Variation increases in response to exploitation. Martin (1966) observed 2-4 fold and 5-10 fold variation in piscivorous and planktivorous popl'ns.
Relative Abundance at Recruitment Age	0.42	0.52	0.73	
Growth	slow/ fast	slow	average	Compared to Ontario average.
Fork length at age 6 (cm)	27.2	34.3	38.2	Ontario average=39.6 - Growth usually increases in response to exploitation.
Mean Age at Maturity (Probit)	5.8	4.6	5.7	SPOF 15 indicate 6 is low for females. Decrease in response to exploitation.
t-value	0.4	1.8	0.3	Whitefish may need t=1.5 to maintain popl'n levels (Christie 1963).
Food Habits	Benthic Inverte-brates/ Piscivores	Plankti-vores	Piscivores	

to determine the state of a fishery. Low yields can occur both at low levels of exploitation or when past overexploitation has occurred. High yields suggest overexploitation though high yields may be sustained early in the development of a fishery. Our study lakes have been exploited for many years and presumably can no longer sustain high yields.

Thus, yield is a function of fishing pressure and abundance and these variables must be considered simultaneously. Obviously low effort and low abundance lead to low yields while high effort and high abundance produce high yields. Neither of these situations occur in our lakes, but consider the following combinations of variables resulting in low or high yields:

1) high abundance, low effort = low yield;

2) low abundance, moderate/high effort = low yield;

3) high abundance, low/moderate effort = high yield;

4) low abundance, high effort = moderate to high yield.

Our study lakes should fit somewhere within these combinations. The first and third possibilities represent desirable situations while the second and fourth may indicate that the population has been overexploited in the past (2) or is currently being overexploited (4).

In our view, an effort of 5 angler-hours/ha represents a 'low' to 'moderate' level of fishing effort on a lake trout lake. This level of effort occurs, for example, on the relatively remote interior lakes of Algonquin Park (Hicks 1985). Thus we consider fishing pressure to

be very high on Dickey Lake (21.6 angler-hours/ha), moderately high on Twelve Mile (9.1) and moderate on Drag Lake (5.8).

Abundance, as measured by angler CUE, was about three to five times higher in Drag Lake (0.266) compared with Dickey (0.099) and Twelve Mile (0.060) Lakes. Lake trout yield was very high in Dickey Lake (0.82 kg/ha/yr, RORY=113%), moderately-high in Twelve Mile 0.46, RORY=78%) and comparatively low in Drag (0.33, RORY=66%). Martin and Olver (1980) suggest that it is unlikely for lake trout populations to withstand annual yields in excess of 0.5 kg/ha/yr. Clearly, a RORY greater than 100% (e.g. Dickey Lake) indicates an excessive yield. Thus, of the limited combinations of yield, abundance, and effort presented above, Drag and Dickey Lakes may tentatively be fit into combinations 1 and 4 respectively. Yield in Twelve Mile Lake was not as high as in Dickey Lake and therefore would be classified somewhere between combinations 2 and 4.

Tentative conclusions thus far are as follows. Drag Lake was not overexploited during the study period (1981-85). High CUE's suggest that it has not been overexploited in the past. Dickey lake was clearly overexploited during the study period, however, the high yields suggest that it was not overexploited in the past. Twelve Mile Lake may not have been overexploited during the study period but low CUE's indicate past overexploitation.

If these classifications are correct, we would expect that the variation in abundance would be highest for Twelve Mile Lake. The

coefficient of variation in abundance was greatest in Twelve Mile Lake (C.V. = 0.61 in winter and 0.81 in summer) followed by Dickey (0.43 and 0.26) and Drag (0.32 in both seasons) Lakes. The higher variation in abundance than that recommended by SPOF 15 (0.35, Ontario 1983) in Twelve Mile and Dickey (winter only) Lakes, may indicate stressed populations in both lakes. We predict that variation in abundance will increase in Dickey Lake as a result of the high annual yields observed in this lake over the study period.

Ratios of observed to recommended lake trout yield less than 100% (Drag and Twelve Mile) do not necessarily indicate a low level of exploitation. For example, the fishery may have stabilized at a low level of abundance due to other stresses, such as alteration of habitat (spawning) or species introductions, such that overexploitation may occur at a lower yield (Colby 1984). A lake's potential yield, as estimated by MEI, can only be considered a first approximation.

Creel surveys can accurately determine angling pressure and yield for a lake. Accurate estimates of relative abundance are much more difficult. Angler CUE only measures the abundance of fish vulnerable to anglers. This may not accurately reflect a true relative population abundance. For example, very recent changes in the abundance of young fish, not vulnerable to the fishery, or a declining catchability with age, will not be detected. These problems could be overcome with independent sampling programs designed to assess the

abundance of specific age groups or mark-recapture programs designed to assess angler selectivity (eg. Laarman and Ryckman 1982).

Age Structure - Mortality

Overexploitation drives total annual mortality rates to high levels and eventually results in the collapse of a fishery. Total annual mortality was greater in Dickey (A = 0.79) and Drag (0.72) Lakes than that recommended by SPOF 15 (0.50, Ontario 1983, see also Healey 1978). However, both these lakes showed trends of increasing lake trout abundance (Figure 2ab) which may have artificially increased our estimates of mortality. As a check on the magnitude of this bias, we calculated mortality from the HUE's of individual cohorts. Mortality ranged from 0.35 to 0.62 (mean = 0.49) for four cohorts in Drag Lake, suggesting our previous estimate of 0.72 is too high. In Dickey Lake, the mortality estimate for two cohorts was 0.63 and 0.80 suggesting that our original estimate of 0.79 may only be marginally elevated. The original estimate of total annual mortality for Twelve Mile Lake (0.49) was close to the maximum level recommended by SPOF 15 (Ontario 1983). There was insufficient data to calculate mortality rates for individual cohorts in Twelve Mile Lake. However, there were no apparent trends in abundance to influence our original mortality estimate.

There is some evidence for walleye to suggest that estimation of mortality based on angler catch is higher than those based on index

netting (see Figure 1 in Elsey and Thompson 1977). Older lake trout may be less susceptible to anglers due to spatial segregation of age classes or selective angling techniques. We may have overestimated mortality for these reasons.

Aging errors can also influence mortality estimates. Older lake trout are subject to underaging when using the scale method (see discussion in Healey 1978). However, the Heincke method of calculating mortality used in the present study does not require accurate age determination for older age classes. Considering that mortality for Drag Lake was overestimated, the mortality rates for each population support our tentative classification of the levels of exploitation based on yield, effort, and abundance (see also Appendix B).

Mean Age of the Harvest

We observed consistent mean ages (approx. 6 years of age) of angled lake trout among lakes and sampling years. Reduction in mean age could reflect an increase in mortality attributable to overexploitation. We saw no such reduction in mean age over the period 1981-85. The mean ages reported here will be useful for future comparisons but could not be used to assess current or past levels of exploitation.

Mean age of the harvest is not necessarily reduced due to overexploitation if young and old fish are equally vulnerable to

angling (Colby 1984). Also, variation in mean age is most often caused by variation in recruitment (Ontario 1983, see below).

Variation in Year Class Strength

Variation in year class strength was high in Dickey and Twelve Mile Lakes and low in Drag Lake. Assuming that perturbation disrupts population stability, then exploitation acting in combination with other environmental factors may increase variation in year class strength (eg. percids, Spangler et al. 1977). Martin and Fry (1972) found that lake trout year class strength was correlated with spawning escapement in Lake Opeongo and suggested that exploitation increased variation in year class strength by limiting recruitment in some years.

The higher variation in Twelve Mile and Dickey Lakes suggest that their lake trout populations are stressed. The methods used to estimate the relative abundance at recruitment age, assumed constant survival and catchability. We have shown that survival may not be constant. However, the generally good agreement between the observed HUE's and our integrated estimates of relative abundance at recruitment age, suggests that the method is reasonably robust. Furthermore, by integrating samples, the estimates are less sensitive to sampling error and allowed assessment of the relative abundance of cohorts not sampled at recruitment age.

The cause of the apparent increase in abundance of the more

recently recruited cohorts in the Drag and Dickey Lake fisheries (Figure 2ab) is not clear and may be a chance event. There has been no known recent improvement in spawning habitat. Density dependent factors, such as intraspecific population regulation coupled with variable planted fish stocking densities, may influence observed trends but such possibilities have not yet been studied.

Catch-at-age analysis (Deriso et al. 1985) would be an excellent alternative to our method, however, the data requirements would limit the analysis to the Drag Lake fishery. Our method may be particularly useful when creel survey data are collected intermittently.

Growth

Lake trout growth in Dickey Lake is slow, but typical of planktivorous populations, and in Twelve Mile is similar to the Ontario average. Drag Lake lake trout show an interesting pattern of growth that is likely related to changes in diet with age. Young lake trout (age < 7) are primarily benthic feeders (diet includes mayfly nymphs, gammarus, amphipods, corregonid eggs, and a few small fish). It has been hypothesized that these fish likely compete with lake herring for a common food resource (Irwin 1983, D. Loftus pers. comm.), thus growth is slow. Growth of older fish is rapid and may be due to increased consumption of fish prey, mainly herring and young of the year smallmouth bass.

Growth in fish is highly plastic (Brett et al. 1969, Weatherley

et al. 1979). As such, growth may be very responsive to exploitation. However, it may prove difficult to distinguish between exploitation and other factors (eg. change in abundance of preferred prey items) as causing changes in growth rate.

Exploitation may increase growth due to reduced stock size and increased food availability (see Healy 1978). However, growth can appear to decrease if exploitation selectively removes the largest, fastest growing individuals (Colby 1984).

In our study lakes, long term monitoring of growth patterns,diet, and food availability will be necessary to isolate the effects unique to exploitation.

Age at Maturity

Mean age at maturity ranged from 4.6 years in Dickey Lake to 5.7 and 5.8 in Twelve Mile and Drag Lakes respectively. Lake trout age at maturity is lower in heavily exploited lakes (Healey 1978) and in lakes where natural predation occurs (eg. harbour seals - Power and Gregoire 1978). The SPOF 15 Working Group (Ontario 1983) reports that a mean age at maturity of 6 for female lake trout represents comparatively early maturation in piscivorous Ontario lake trout populations. The low age at maturity in our lakes suggest high levels of exploitation, especially in Dickey Lake, though planktivorous (slow growing) lake trout mature at a smaller size and younger age than piscivorous populations (Martin 1966).

Abrosov's t-values ranged from 0.3 and 0.4 in Twelve Mile and Drag Lakes respectively to 1.8 in Dickey Lake. The t-value is a measure of spawning escapement indicating the number of spawning opportunities for the 'average' individual. However, both mean age of the catch and mean age at maturity in a population are responsive to exploitation and the relative sensitivity and magnitude of their responses is unknown. Thus, though the t-value is high in Dickey Lake suggesting sufficient spawning escapement, the low age at maturity suggests overexploitation.

Both the mean and range of ages for spawning stocks were greater in Drag than Twelve Mile Lake. The wide range of successive age classes (5 to 17 years) indicate that the spawners in Drag Lake were not a remnant population. Thus there was greater spawning escapement in this lake. Further, we observed increasing recruitment over the study period in Drag Lake suggesting more than sufficient spawning escapement to maintain the fishery at current levels of angling effort.

Although data on the age composition of the spawning stock in Dickey Lake is unavailable, the maturity and spawning shoal data support our tentative classification of the level of exploitation on each study lake.

Maturity schedules are normally reported for females only, since maturity in males is more difficult to assess (Healey 1978). Though maturity classifications remain somewhat subjective, our results are

at least consistent among lakes. Ritchie (1984) discusses the various methods used to calculate age at maturity, therefore, these will not be reviewed here.

Summary

1) Drag Lake was not overexploited during the study period (1981-85). Angling effort was moderate, CUE was high, and annual yield was not excessive. Mortality rate was likely overestimated. Growth was slow for young fish (age 7) but very fast thereafter. Spawning escapement was sufficient to allow increased recruitment over the study period.

2) Dickey Lake was clearly overexploited during the study period. Effort, yield, mortality, and variation in abundance were high but CUE's were relatively low. The very high yields suggest that either overexploitation has not occurred in the past or that Dickey Lake is capable of sustaining high yields. Growth was slow but typical for planktivorous populations in Ontario. Abrosov's t-value was relatively high suggesting potentially good spawning escapement. However, the low CUE's and high variation in abundance indicate insufficient spawning escapement. The very low age at maturity also suggests a stressed population. The level of lake trout exploitation should be reduced on Dickey Lake.

3) Twelve Mile Lake may not have been overexploited during the study period. Effort, yield, and mortality were all considered moderate to high. However, very low angler CUE's and high variation in abundance and year class strength indicate that Twelve Mile Lake has likely been overexploited in the past. Growth was similar to the Ontario average

for lake trout. A relatively young age distribution of spawning fish may suggest excessive exploitation rates and insufficient spawning escapement. Lake trout exploitation should be reduced on Twelve Mile Lake.

4) Mean ages did not prove useful in assessing the level of exploitation but may prove useful as baseline values for future comparisons on our lakes. Greatest variation in mean age occurred in Twelve Mile Lake consistent with its high variation in abundance and year class strength.

Assessment Priorities

Recruitment has increased in Drag and Dickey Lakes in recent years, however, the data series is too short to indicate a trend. More detailed catch-at-age analysis should be applied to the data series of Drag and Dickey Lakes to confirm these observations. If recruitment continues to increase, future improvements in the fishery may erroneously be attributed to the winter angling closure beginning in 1987.

The low CUE and high variation in year class strength in Twelve Mile Lake is symptomatic of a stressed fishery. Similarly, all indications are that Dickey Lake is currently being severely overexploited. Unfortunately, these fisheries are not scheduled for assessment by the regular assessment program until 1990/91. Therefore, any opportunity to continue monitoring these lake trout populations in the iterim, should be given serious consideration.

Consideration must be given to the implementation of sampling programs designed to determine the relative abundance of specific age/size groups of lake trout. Knowledge of the abundance of young fish, not vulnerable to angling, could be used to determine the survival at ages prior to recruitment to the fishery. Such data would result in a better understanding of the determinants of year class strength for lake trout. Independent estimates of relative or absolute abundance of age groups vulnerable to angling would allow

determination of catchability, thus improving estimates of fishing and natural mortality.

Index netting of spawning stocks provided valuable information on spawning escapement and the relative abundance of old fish in Drag and Twelve Mile Lakes. Spawning stocks should be sampled on Dickey Lake and at regular intervals on all lakes (perhaps at the beginning and end of the five year sampling cycle). However, the relationship between recruitment, exploitation, and the age distribution of the spawning stock, is not fully understood. In this respect, knowledge of the influence of behavioural interactions on the age distribution of spawning populations would be extremely useful.

Maturity indices remain subjective. More objective means of determining state of maturity are necessary to standardize this measure.

Better methods, to assist managers with extrapolating assessment unit intelligence to a larger number of managed lakes, need to be developed. By synthesizing and analysing subsets of assessment unit data, it may be possible to recommend minimal, cost effective, assessment programs which districts could implement on a number of lakes. For example, a synthesis of yield, effort, and abundance from a number of assessment unit lakes (see Ontario 1984), where at least a tentative assessment of the level of exploitation has been made, would provide more appropriate guidelines to fisheries managers.

Our approach to lake trout exploitation stress assessment was to

examine population attributes following SPOF 15 (Ontario 1983). As similar studies accumulate, it will be possible to refine existing methods and develop additional population indicators of exploitation stress. Community attributes such as competitor and prey types (Goddard et al. 1986), or even zooplankton community structure (eg. Mills and Schiavone 1982) may also characterize lake trout fisheries. Thus, community analysis would provide a valid alternative or additional approach. However, community responses to exploitation stress and the effects of community characteristics on lake trout yields are intricate and only beginning to be appreciated.

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Appendix A

In this report of lake trout exploitation assessment, we based our conclusions regarding age structure biological attributes (total annual mortality, mean age of the harvest, and variation in year class strength) on winter HUE data for reasons cited in the text. In this appendix we include data to substantiate these reasons (Appendix A, Table 1) and, in addition, we contrast winter and spring/summer estimates of mortality, mean age, and variation in year class strength (Appendix A, Table 2).

Mortality: Winter and spring/summer mortality estimates were similar except in Drag Lake where the mortality estimate was lower in summer.

Mean Age of the Harvest: Mean age of the spring/summer harvest was significantly greater for females in all lakes. Mean age was greater in the spring/summer season in Drag and Twelve Mile Lakes. In Dickey Lake, mean age was similar in both winter and spring/summer seasons.

Variation in Year Class Strength: Coefficients of variation values for both mean age and relative cohort abundance at recruitment age ($q \cdot N_R$) varied between winter and spring/summer seasons. The spring/summer data, contrary to previous conclusions, suggested that least variation in year class strength occurred in Dickey Lake. Recruitment patterns based on spring/summer data were also different from those based on winter data.

We attribute discrepancies between winter and spring/summer estimates mainly to:

1) high variation in our summer estimates of HUE by age due to small sample size (number of years and aged fish) and aging errors; and 2) high variation in catchability due to growth and variation in angling methods over the spring/summer season.

We maintain that conclusions based on our best samples (winter data) are better founded and suggest caution when making interpretations based on summer data alone. This issue will become especially relevant with the recent closure to winter angling in Drag Lake.

Appendix A. Table 1. Mean annual winter and spring/summer effort, catch, harvest, and sampling statistics for the lake trout fisheries of Drag, Dickey and Twelve Mile Lakes.

	ang-hrs/ ha (%)	% Effort Observed	Catch (%)	Harvest (%)	% Harvest Observed	Aged Sample (%)	No. Seasons Sampled
Drag Lake							
Winter	3.1 (53)	19.9	867 (73)	681 (77)	19.1	118 (83)	5
Spring/ Summer	2.7 (47)	15.0	317 (17)	199 (23)	12.1	25 (17)	4
Year	5.8	17.6	1184	880	17.5	143	
Dickey Lake							
Winter	12.0 (56)	34.3	268 (52)	178 (50)	31.5	61 (51)	5
Spring/ Summer	9.6 (44)	19.8	193 (48)	176 (50)	23.3	59 (49)	3
Year	21.6	27.9	461	354	27.4	120	
Twelve Mile Lake							
Winter	6.7 (74)	28.0	203 (65)	180 (67)	26.1	45 (79)	4
Spring/ Summer	2.3 (26)	13.9	109 (35)	87 (33)	11.5	12 (21)	4
Year	9.0	24.4	312	267	21.3	57	

Appendix A. Table 2. Comparison of winter and spring/summer estimates of mortality, mean age of the harvest, and variation in year class strength in Drag, Dickey, and Twelve Mile Lakes.

		Drag	Dickey	Twelve Mile
Total Annual Mortality				
Winter		.72	.79	.49
Spring/Summer		.51	.77	.52
Mean Age of the Harvest				
Winter		5.8	6.3	5.8
Spring/Summer		7.1	6.2	6.6
	Male	6.4	5.9	6.4
	Female	7.3	6.4	7.2
Variation in Year Class Strength				
Coefficient of Variation:				
Mean Age	Winter	.05	.06	.07
	Spring/Summer	.16	.03	.10
$q \cdot N_R$	Winter	.42	.52	.73
	Spring/Summer	.71	.42	.82

Appendix B

We used the Heincke method to estimate total annual mortality. The advantage of this method is that it can be used when age determinations of older fish (beyond the age of full recruitment) are unreliable (Ricker 1975). The disadvantage is that the method attaches a lot of weight to the sample of fish in the first year of full recruitment. A poor sample or variable recruitment can cause errors in the mortality estimate. To overcome this problem, we aggregated age distributions over all sampling years. Nevertheless, we included this appendix to contrast Heincke mortality estimates with those obtained by catch curve analysis (Ricker 1975). Mortality estimates were calculated based on regressions of catch curves for both "unsmoothed" and "smoothed" (with a running average of 3, Ricker 1975) data (Appendix B Table 1). Mortality estimates based on catch curve analysis were marginally less than those of the Heincke methods for Drag and Dickey Lakes but substantially higher for Twelve Mile Lake. The higher mortality estimates for Twelve Mile Lake agrees favourably with our assessment that this lake has suffered past overexploitation. We conclude that we were not misled by mortality estimates based on the Heincke method.

Appendix B. Table 1. Comparison of total annual mortality estimates calculated by the Heincke method and catch curve analyses. For the second estimate based on catch curve analysis, data were "smoothed" with a running average of 3. Age distribution samples were aggregated over all years for winter harvested fish.

	Heincke Method	Catch Curve Analysis	
		"unsmoothed"	"smoothed"
Drag	.72	.68	.65
Dickey	.79	.77	.72
Twelve Mile	.49	.59	.67